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„Don't Panic!"

A Beginner's Guide to Life Cycle Assessment (Without Panicking)

This project is co-funded by the European Union through the Interreg Alpine Space programme

This guide was created in cooperation with Magdalena Winkler, MSc, who kindly provided parts of the findings of her master's thesis as contribution to the chapters of this guide. The thesis was written to conclude the master's program "Innovation and Product management" at the University of Applied Sciences Upper Austria Campus Wels. Sources used within the thesis and in this guide can be found within the Help Guidepost on the last page.

Introduction: A Journey through your Sustainability

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Life Cycle Assessment (LCA) is like having your very own Babel fish for understanding the environmental footprint of your products and services. It translates complex processes – raw material extraction, production, use, and disposal – into a clear, structured narrative. **Think of it as the ultimate guide to identifying where resources are lost, emissions spewed, or waste piled up. LCA doesn't just reveal the environmental hotspots – it hands you the map and the instructions to navigate them with confidence.**

For small and medium-sized enterprises (SMEs), diving into LCA can feel as daunting as hitching a ride on a Vogon spaceship. But don't panic! The process is systematic and flexible, helping you spot opportunities for improvement that are both practical and profitable. Imagine swapping out resource-heavy suppliers for greener alternatives or tweaking production to reduce energy use – simple adjustments that can make a huge difference. In an increasingly eco-conscious galaxy, customers, investors and regulators are looking for business that boldly goes where sustainability matters. With LCA, you're not just keeping up; you're leading the way, one informed decision at a time.

Life Cycle Assessment (LCA) can be done using specialized software tools or just Excel, and each comes with its pros and cons. Tools like SimaPro, OpenLCA, or GaBi are packed with built-in databases, automated calculations, and great visualization options, making them very efficient and accurate – especially for more complex projects. Excel, on the other hand, is cheaper and super flexible, but also more prone to user error. Ultimately, the right choice depends on how complex your project is, your budget, and what tools you're comfortable working with. This guide also includes some support on how to make the right choice when it comes to those tools. But before getting into all of that, let's look into what an LCA is and why doing one matters.

What is Life Cycle Assessment

Life Cycle Assessment (LCA) is a standardized method (ISO 14040 and 14044) for assessing the environmental impact of a product or system throughout its entire lifecycle – from raw material extraction to end-of-life disposal. Essentially, it's about compiling and evaluating all the inputs (like energy and materials) and outputs (like emissions or waste) to understand the potential environmental impacts (ISO, 2006-a). While LCA is systematic, iterative, and flexible, it's important to note that it calculates potential impacts rather than predicting what will happen in the real world. The methodology is broken into four phases: goal and scope definition, life cycle inventory analysis, life cycle impact assessment, and the interpretation and presentation of results.

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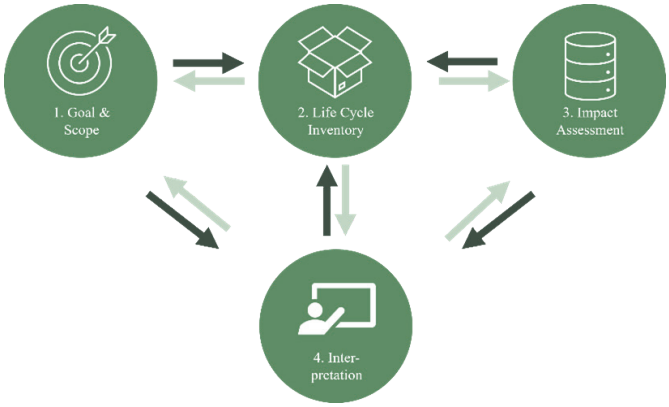


What can **you** do with LCA

LCA is an incredibly versatile tool that can support decision-making, learning, exploration, and communication across various areas of a business (Baumann & Tillman, 2004). In product development, it can guide design decisions; in procurement, it can help choose suppliers; in product management, it identifies areas for improvement; in marketing, it supports eco-labeling efforts; and in management, it aids strategic planning (Baumann & Tillman, 2004; ISO, 2006-a). Beyond companies, LCAs also help governments craft better policies and enable consumers to make more sustainable choices in their everyday lives (Hauschild et al., 2018.

Important terms

- *Functional Unit and Reference Flow:* LCAs are always calculated in relation to a functional unit – a quantitative measure of the product's function. For example, when comparing paper towels and hand dryers, the functional unit might be „the number of dried hands." The reference flow then quantifies what's needed to perform that function, like the number of towels or the amount of hot air required (ISO, 2006-a).
- *System Perspective and System Boundaries:* An LCA views a product as part of a „system" of processes and flows needed to perform its function. For instance, making bottle caps might include processes like injection molding, with input flows (plastic material, electricity) and output flows (finished caps, heat from the process). System boundaries determine which processes and flows are included in the assessment (Baumann & Tillman, 2004).
- *Allocation:* This refers to dividing the inputs and outputs of a process among multiple products. For example, if one process produces both a main product and by-products, allocation ensures the environmental impacts are fairly distributed (ISO, 2006-a).
- *Impact Categories:* These represent the environmental consequences of activities in the product system. Common examples include climate change, acidification, and eutrophication (ISO, 2006-a).

Mapping the Journey: Defining your goals

"O Deep Thought computer," he said, „the task we have designed you to perform is this. We want you to tell us...." he paused, „The Answer."

– Douglas Adams, The Hitchhiker's Guide to the Galaxy

When starting an LCA, it's crucial to define the goal and scope. This is the first phase of the process, where you establish the purpose, target audience, and how you will

use the results in the end (ISO, 2006-b, p. 7). A clear and well-defined goal helps ensure the study is focused and relevant, guiding the entire process. By aligning the LCA with specific objectives, you minimize wasted effort and ensure that the results will be actionable for your company.

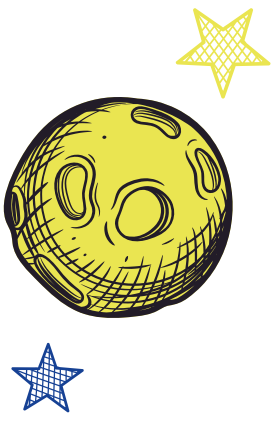
Once the goal is clear, you can decide on the boundaries and specific aspects of the LCA, like modeling requirements (Baumann & Tilman, 2004). The scope specifies the parts of the product or service life cycle that will be assessed and helps avoid overlooking important impacts. It also sets limits to avoid making the study too complex or unrealistic.

When starting an LCA, the goal and scope definition is your first step, and it sets the foundation for the entire process. According to ISO 14044, here's what you need to think about:

- *What you're studying:* Define the product or system and what it does (its function).
- *System boundaries:* Decide which parts of the product's life cycle you'll include, like production, use, or disposal.
- *Functional unit:* Set a clear measure of what you're comparing, like "one dried hand" for comparing paper towels vs. hand dryers.
- *How to handle shared impacts:* If processes produce more than one product, plan how to fairly divide the environmental impact between them (allocation).
- *Data needs:* Define what data you need, its quality, and any assumptions you'll make.
- *Impact categories:* Pick the environmental impacts you'll measure, like climate change or water use.
- *Analysis methods:* Decide on tools and methods for calculating impacts (LCIA).
- *Limitations:* Be clear about any limits or uncertainties in your study.
- *Reporting:* Plan how you'll present the results and who will review the study.

It's best to work through the goal and scope definition in collaboration with all relevant parties in your company. Input from multiple stakeholders, such as engineers, environmental managers, and decision-makers, ensures the study captures all relevant aspects. While it's important to get as much detail as possible, it's also common and recommended to revisit this phase later. Clear definitions at this stage ensure transparency and help trace the entire process (Baumann & Tilman, 2004).

The goal and scope definition are essential because the decisions made here directly influence later stages, such as data collection. Furthermore, it helps shape how results will be interpreted. The choices made during this phase have a lasting impact on the conclusion and recommendations that can be drawn later on (Hauschild et al, 2018). Without a clear goal and scope, the LCA might not provide meaningful or reliable insights.



Collecting the Essentials: Data gathering basics

"A towel, [The Hitchhiker's Guide to the Galaxy] says, is about the most massively useful thing an interstellar hitchhiker can have."

- Douglas Adams, The Hitchhiker's Guide to the Galaxy

The second phase of an LCA is called life cycle inventory analysis (LCI), and it's all about collecting and organizing the data you need. It's broken down into three main steps (ISO 2006, p. 11ff):

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- *Data collection:* Start by sketching out a flow diagram of your product system that includes all the processes, flows, and connections. Make sure to define the units for each flow and document key details like sources, how the data was collected, and any time or quality criteria – especially for critical information.
- *Data calculation:* This step involves crunching the numbers and making sense of the data you've gathered. Document all calculations, assumptions, and the general approach you've taken. You'll also need to validate the data, connect it to the functional unit, and refine the system boundaries as needed.
- *Allocation:* If your system involves shared processes or outputs, you may need to apply allocation methods to fairly distribute impacts. It's important to be consistent in how you handle similar inputs and outputs. The standard also provides guidance on managing reuse and recycling.

At the end of this phase, you'll have your life cycle inventory: a detailed list of all the physical flows tied to your functional unit. These flows are quantified, often with the help of generic datasets (Hauschild et al., 2018).

Navigating Impact Assessment: From raw materials to end-of-life

"We demand rigidly defined areas of doubt and uncertainty!"

- Douglas Adams, The Hitchhiker's Guide to the Galaxy

Phase 3, the Life Cycle Impact Assessment (LCIA) is where the magic of LCA truly happens – it's where data from the inventory phase gets translated into environmental impacts. This process provides insights into how a product, or a system affects the environment throughout its life cycle, from raw material to disposal (Hauschild et al., 2018). While this may sound complex, modern software automates much of the work (learn more in chapter "Making good choices: Selecting the right tool"). The key responsibility for the practitioner is to select the right LCIA method and settings, ensuring they align with the study's goals and scope (ISO, 2006-b).

Environmental impact categories

Impact categories are the backbone of LCIA. They represent environmental challenges that we aim to address. Some of the most common include:

- *Climate change:* How greenhouse gas emissions contribute to global warming.
- *Stratospheric ozone depletion:* The thinning of the ozone layer caused by specific pollutants.
- *Acidification:* The acidification of ecosystems due to emissions like sulfur dioxide.

Some categories, like climate change, are well-developed with established methods, while others are still evolving.

Step-by-Step Process of Impact Evaluation

The LCIA phase typically follows three key steps (ISO, 2006-b, p. 16ff):

- *Defining Impact categories and indicators:* This step involves selecting the impact categories (e.g., climate change), defining indicators (e.g., infrared radiative forcing for climate change), and choosing characterization models (e.g., the IPCC baseline model for Global warming potential over 100 years). Table 1 from ISO 14044:2006 provides clear examples:

Term	Example
Impact category	Climate change
LCI results	Amount of greenhouse gas per functional unit
Characterization model	Baseline model of 100 years of the Intergovernmental Panel on Climate Change
Category indicator	Infrared radiative forcing (W/m^2)
Characterization factor	Global warming potential (GWP100) for each greenhouse gas (kg CO2-equivalents/kg gas)
Category indicator result	Kilograms of CO2-equivalents per functional unit
Category endpoints	Coral reefs, forests, crops

Table 1: Explanation of LCIA terms through examples (ISO, 2006-b, p.18)

- *Classification:* Inventory data from the previous phase is sorted into the relevant impact categories. Some data points affect only one category, while others may influence several. Practitioners must handle these overlaps carefully, differentiating between parallel and serial effects (ISO, 2006-b).
- *Characterization:* Finally, the classified data is converted into measurable impacts using characterization methods like EF, ReCiPe midpoint, or TRACI. This step quantifies impacts in terms like CO2-equivalents for climate change, making them easier to understand and compare (Janssen, n.d.).

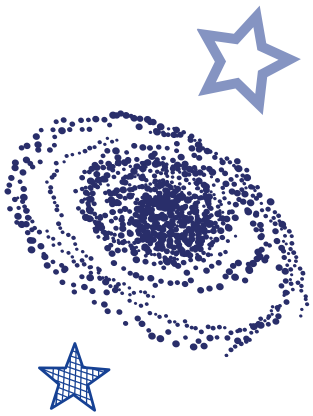
Optional Elements in LCIA

For a deeper analysis, additional steps can be applied, including:

- *Normalization:* Comparing results to a reference value, such as national or global averages.
- *Grouping:* Clustering impact categories based on their importance or relevance.
- *Weighting:* Assigning relative importance to different impact categories.
- *Data Quality Analysis:* Evaluating the reliability of the input data.

While these optional elements are not always required, they can provide valuable context, especially for decision-making (ISO, 2006-b, p.20f).

By breaking down raw data into meaningful insights, the LCIA phase connects the dots between everyday processes and their environmental impact. It's an essential part of turning numbers into actionable understanding.



Crunching the Numbers: Analyzing and interpreting results

"Time is an illusion. Lunchtime doubly so."

- Douglas Adams, The Hitchhiker's Guide to the Galaxy

LCA software tools work by crunching vast amounts of data to evaluate the environmental impact of a product or process across its entire lifecycle. Once you input the necessary data – such as raw material usage, energy consumption, transportation details, and waste outputs – the software uses embedded databases and algorithms to map out and calculate emissions, resource depletion, and other impact categories. These tools streamline the complex calculations of the LCI and LCIA, presenting the

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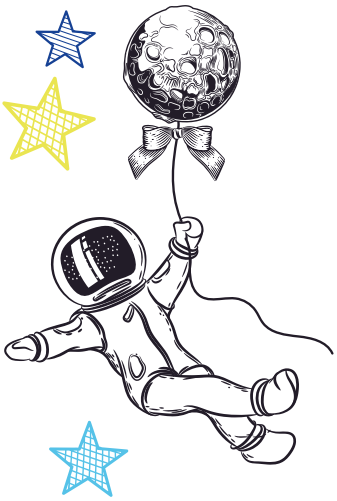
results in structured formats like charts, graphs, and summaries. While the software handles the heavy lifting of data processing, it's up to you to interpret the outputs during the fourth final step of the LCA.

This includes stating significant issues found in the LCIA phase of the study, investigating completeness, sensitivity and consistency of the study, giving final conclusions, and summarizing limitations and recommendations (ISO, 2006-b, p. 23). This phase should be performed with the goal and scope definition in mind, as it should act as a summary and provide answers to previously defined questions (Hauschild et al., 2018).

For small and medium-sized businesses, using LCA results effectively means keeping things practical. For example, if the data shows a supplier's materials have a high environmental impact, you could explore greener options. Or, if a certain production step uses too much energy, you could investigate ways to make it more efficient. Don't worry about having perfect data or answers right away – the goal is to learn, take small steps, and improve over time. Starting simple and focusing on your company's biggest priorities will help you get the most out of your LCA.



Making good choices: Selecting the right tool

"It is a mistake to think you can solve any major problems just with potatoes."

- Douglas Adams, The Hitchhiker's Guide to the Galaxy

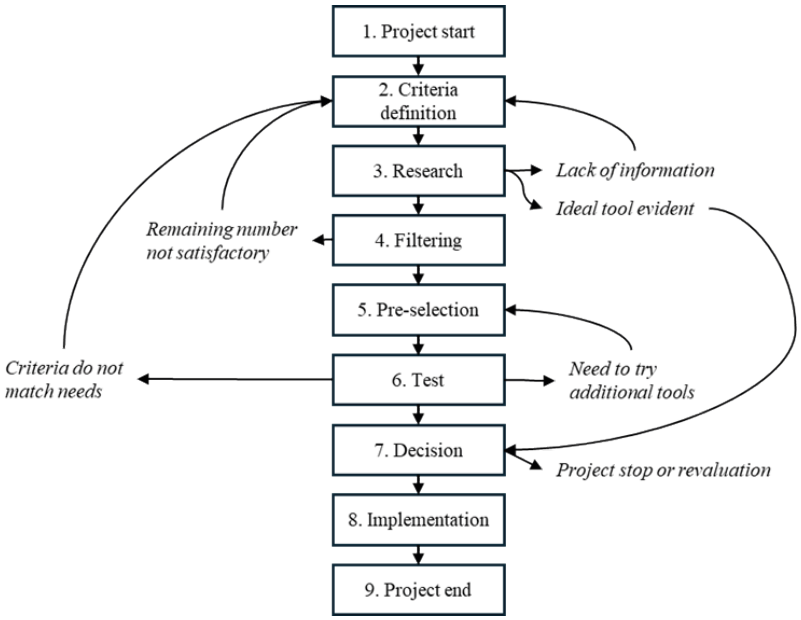
Since a large number of software tools is available, one should first get a clear picture about the context and wanted application. This can be supported by answering questions like "How much expertise on LCA do we already have?", "How much resources are available?", "For what do we need the LCA results and to whom will they be communicated?", "What industry are we in?".

Through the definition of context and situation, a set of criteria can be defined. Those can be differentiated into must haves or exclusion criteria (e.g. fitting industry specialization of the tool) and other important criteria (e.g. usability, functionalities).

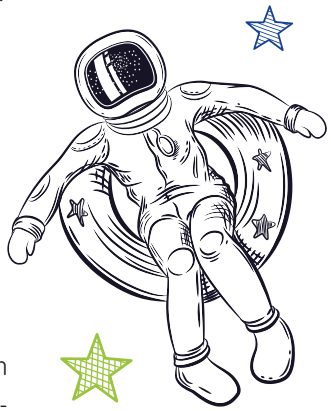
After this, some research on the defined criteria is necessary. An overview of 33 LCA tools with general information is available in the master thesis "Measuring Circular Economy – the Role of Life Cycle Assessment and its Status Quo in Companies" and can act as a starting point.

Once the research phase is concluded, tools that did not meet the previously defined criteria are eliminated. As a next step, two or three tools could be selected for a first test or closer evaluation. To support this, a graphical visualization e.g. on a 2-dimensional plot can help. The axes should reflect the previously defined criteria. Software to which exclusion criteria are applicable should not be further considered. The tools that fit all defined criteria, however, should be further analyzed through an active try-out of the software using test versions, calls with the providers or more research on the software.

Now everything should be ready for the decision about which software to use and the implementation of the software.



Simplified LCA tool selection process by Magdalena Winkler, Peter Hehenberger and Simon Merschak (University of Applied Sciences Upper Austria)



Going Further: Communicating and acting on your findings

"For a moment, nothing happened. Then, after a second or so, nothing continued to happen."

- Douglas Adams, The Hitchhiker's Guide to the Galaxy

Life Cycle Assessment results are most valuable when they lead to meaningful action and are effectively communicated. Different stakeholders – from customers to regulators to employees – have varying interests, so it's important to tailor your communication for maximum impact. For example, customers may appreciate eco-labels or a simple claim like "Made with 30% less energy," while regulators may require detailed reporting to meet compliance standards. Employees, on the other hand, might respond to training sessions that show how their roles contribute to reducing environmental impact. By targeting your messaging, you can ensure everyone understands and supports your sustainability efforts.

When acting on your findings, start small and focus on practical steps that align with your business goals. For example, if your LCA highlights a high carbon footprint in production, look for energy-efficient machinery or renewable energy options. If packaging is a problem, explore recyclable or biodegradable materials. Celebrate these quick wins internally and externally – share success stories through newsletters or social media to show your commitment to improvement. As you tackle bigger changes, like redesigning a product or optimizing supply chains, create a roadmap with clear milestones and involve your team in the process.

To integrate LCA results into your long-term strategy, consider the following steps:

- *Simplify and share:* Create accessible summaries or infographics for internal and external audiences. This helps build awareness and encourages collaboration.
- *Identify priorities:* Focus on areas with the highest impact or easiest opportunities for change. This keeps efforts manageable and results visible.
- *Engage your team:* Involve employees in sustainability initiatives, such as workshops or green challenges. Their ideas can lead to innovative solutions and foster a culture of sustainability.

- *Set goals and track progress:* Use your LCA findings to set measurable targets, like reducing energy use by 20% or eliminating single-use plastics. Regularly review your progress to stay on track.
- *Leverage marketing and reporting:* Showcase your improvements in marketing campaigns and sustainability reports. Transparency builds trust with customers, investors, and partners.

By communicating your findings effectively and turning them into actionable steps, even small and medium-sized businesses can make significant strides in sustainability. Remember, every change – big or small – contributes to a greener future and a stronger business reputation.

Conclusion: Embracing continuous improvement

"Would it save you a lot of time if I just gave up and went mad now?"

- Douglas Adams, The Hitchhiker's Guide to the Galaxy

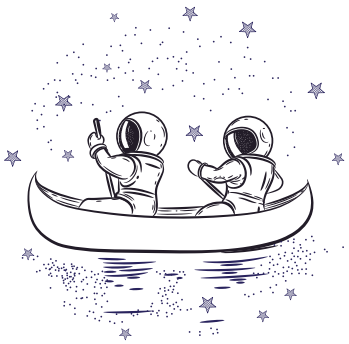
Sustainability is a journey, not a destination, and Life Cycle Assessment is a tool that evolves with your business. To keep your results impactful, it's important to regularly update and refine your LCA processes. Set reminders to revisit your goals, evaluate the relevance of your data, and incorporate new tools or methodologies as they emerge. Continuous improvement ensures that your assessments remain accurate and aligned with both your business needs and the latest environmental standards.

LCA can seem overwhelming at first, but it's a powerful tool for understanding the environmental impact of your products and services. It breaks down complex processes to show where improvements can make the biggest difference – whether it's reducing energy use, cutting waste, or choosing better materials. To make sense of the results, focus on a few key areas that matter most to your business, like carbon emissions or water use. Presenting the findings in simple charts or summaries can help understand the results clearly.

When iterating your LCA, start by analyzing the changes in your operations or supply chain since your last assessment. Are there new materials, processes or regulations to consider? Engage with your team and stakeholders to identify areas where improvements have been made or where new challenges have arisen. Use these insights to refine your goals and recalibrate your focus, ensuring that your sustainability stays on track.

Ultimately, the goal is to embed sustainability into the core of your business. View each LCA step as a step forward, building on past insights and paving the way for greater impact. By committing to continuous improvement, you can transform your sustainability initiatives from a single project into a long-term, value-driven practice that benefits both the environment and your company's success.

Help Guideposts: Resources, advisors, and intergalactic support for your LCA journey



"So long, and thanks for all the fish."

- Douglas Adams, The Hitchhiker's Guide to the Galaxy

ISO Standards

- International Organization for Standardization. (2006-a). Environmental management—Life cycle assessment—Principles and framework (ISO 14040:2006). https://www.iso.org/standard/37456.html
- International Organization for Standardization. (2006-b). Environmental management—Life cycle assessment—Requirements and guidelines (ISO 14044:2006). https://www.iso.org/standard/38498.html

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- Frischknecht, R. (2020). Lehrbuch der Ökobilanzierung. In Springer eBooks. https://doi.org/10.1007/978-3-662-54763-2
- Hauschild, M., Rosenbaum, R., & Olsen, S. (2018). Life cycle assessment. In Springer eBooks. https://doi.org/10.1007/978-3-319-56475-3
- Baumann, H., & Tillman, A. (2004). The hitch hiker's guide to LCA: an orientation in life cycle assessment methodology and application. https://ci.nii.ac.jp/ncid/BA87554388

Publications:

- European Commission, ILCD handbook (2010): General Guide for Life Cycle Assessment – Provisions and action steps (General guide for Life Cycle Assessment - Publications Office of the EU)
- EPA & WBCSD, presentation (2022): Introduction to Life Cycle Assessment methodology and standards (Value Chain Carbon Transparency Pathfinder)
- Magdalena Winkler, master thesis (2024): Measuring Circular Economy – the Role of Life Cycle Assessment and its Status Quo in Companies

Websites:

- European Commission: European Platform on LCA | EPLCA (European Platform on LCA | EPLCA)
- European Commission: Environmental Footprint Methods [Life Cycle Assessment & the EF methods - European Commission)
- UN: Life Cycle Initiative (Home - Life Cycle Initiative)

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